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(54) APPARATUS, METHOD AND SYSTEM FOR PROVIDING REFLECTION OF AN OPTICAL SIGNAL

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H03F 3/08 (2006.01)

(52) **U.S. Cl.**
USPC .... **250/214 A**; 250/216; 250/239; 257/441; 385/15; 385/83; 385/88

(58) **Field of Classification Search**
USPC .... 250/214 A, 208.1, 227.11, 214.1, 250/214 R, 216, 226, 239; 257/431, 432, 257/436; 385/4, 14, 15, 47–52, 65, 83, 88–92
See application file for complete search history.

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(57) **ABSTRACT**

Techniques and architectures for providing a reflective target area of an integrated circuit die assembly. In an embodiment, a reflective bevel surface of a die allows an optical signal to be received from the direction of a side surface of a die assembly for reflection into a photodetector. In another embodiment, one or more grooves in a coupling surface of the die provide respective leverage points for aligning a target area of the bevel surface with a detecting surface of the photodetector.

26 Claims, 6 Drawing Sheets

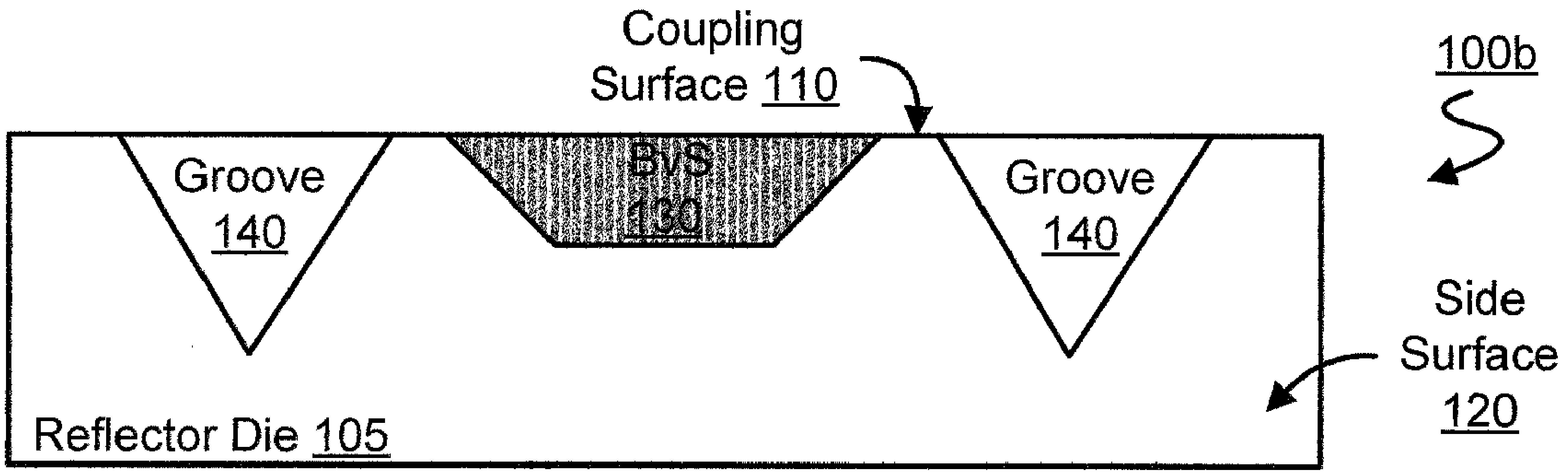


FIG. 1A

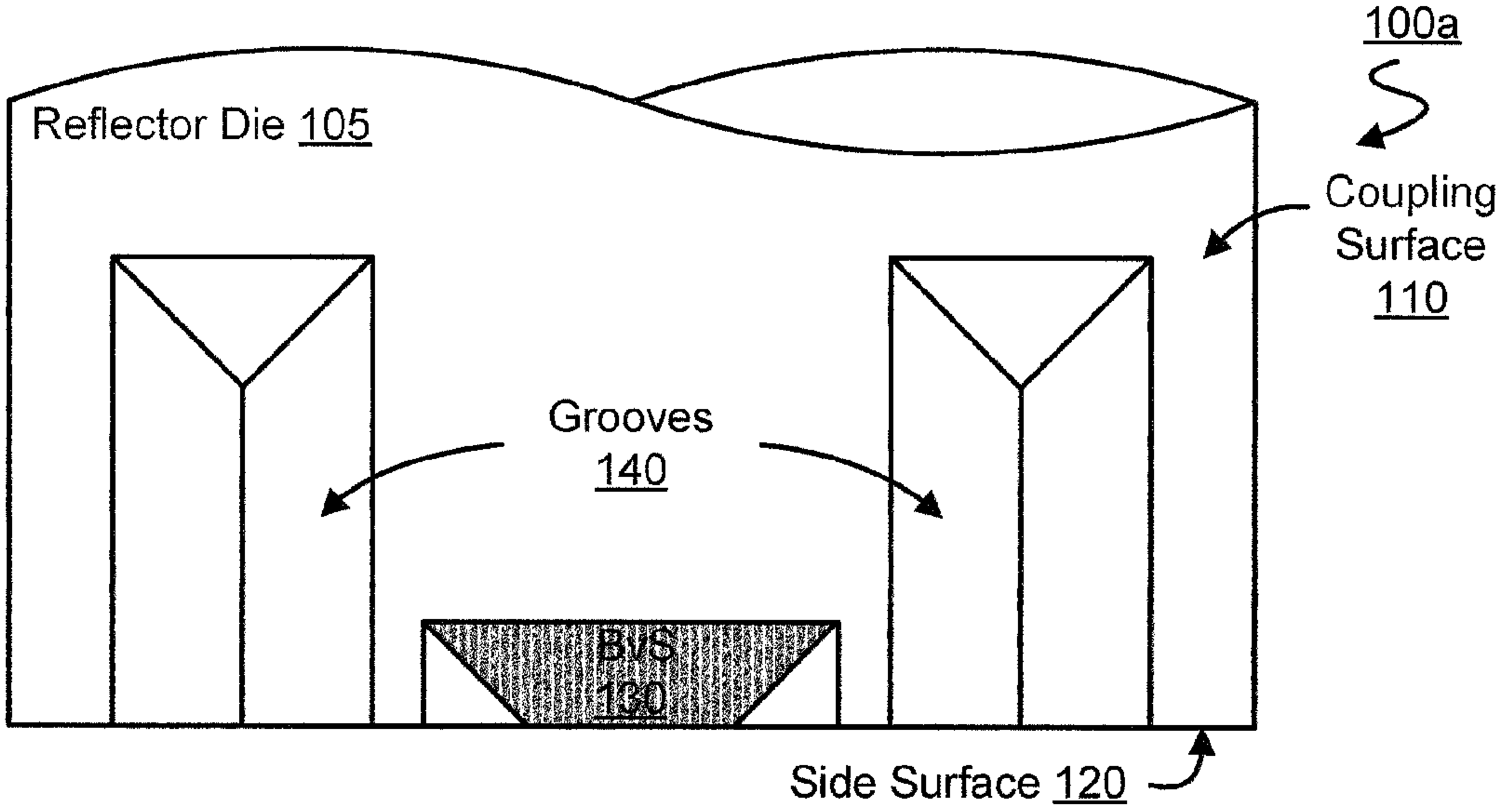


FIG. 1B

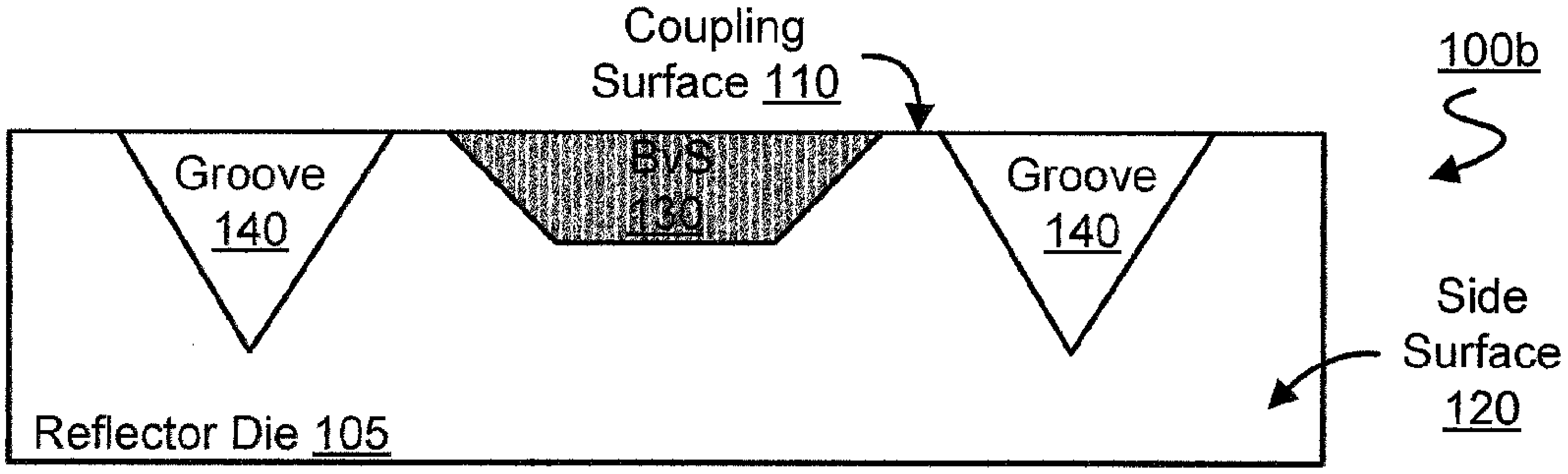
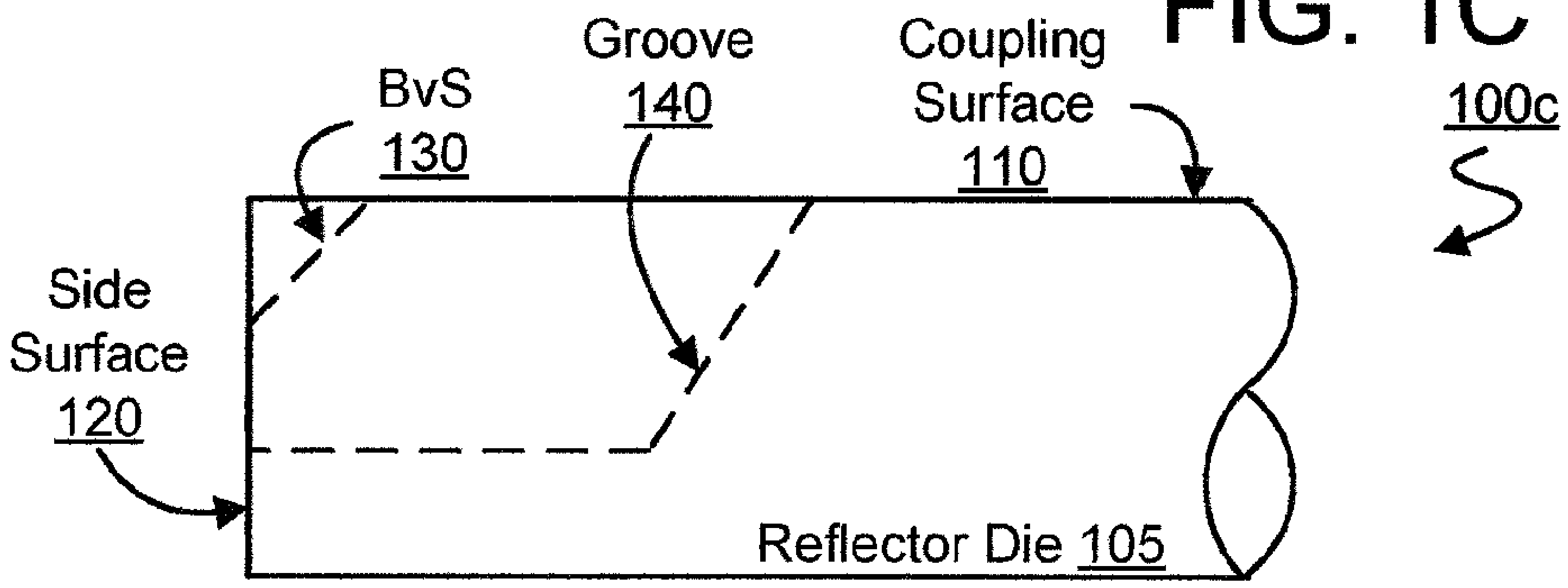


FIG. 1C



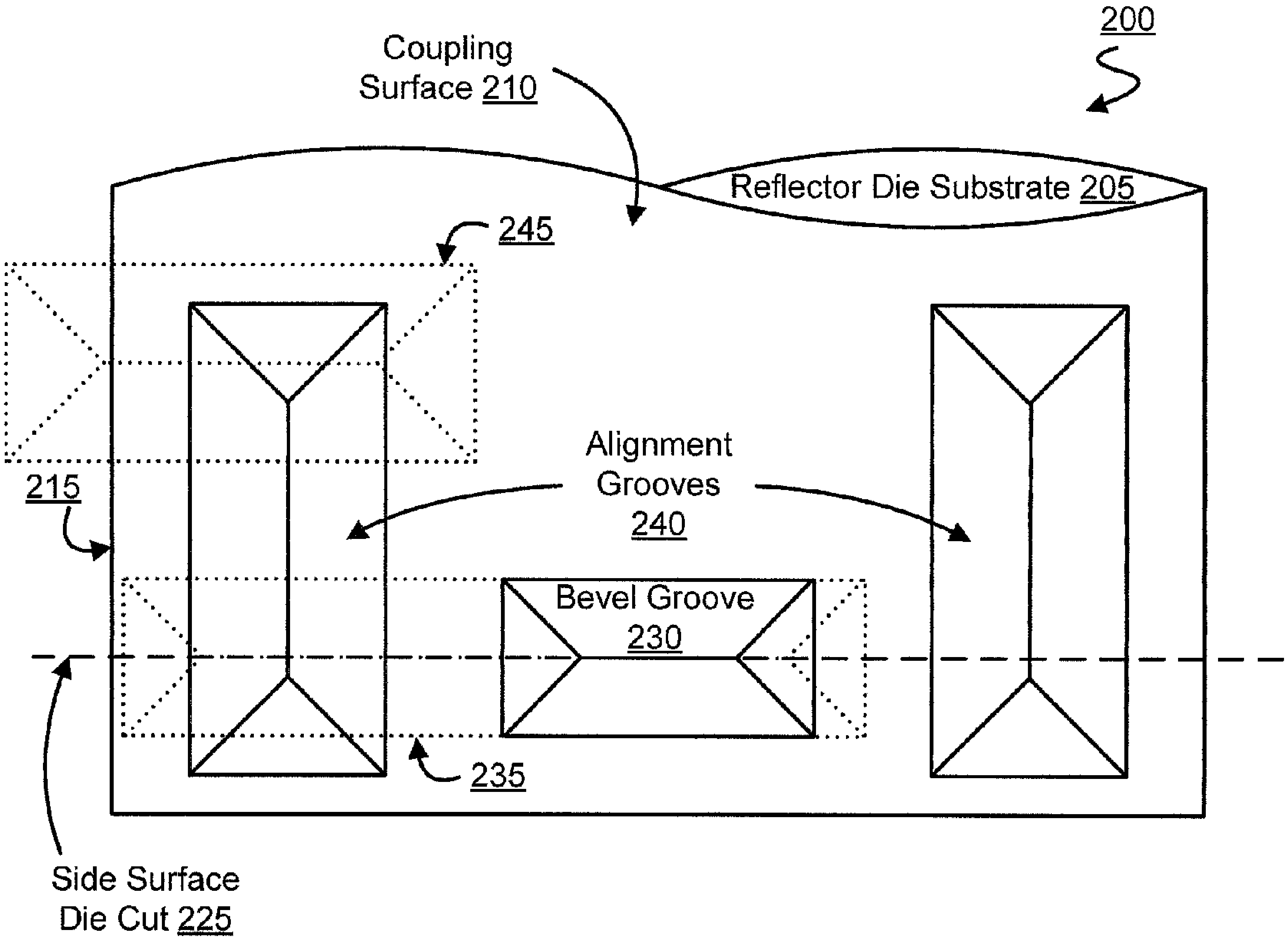
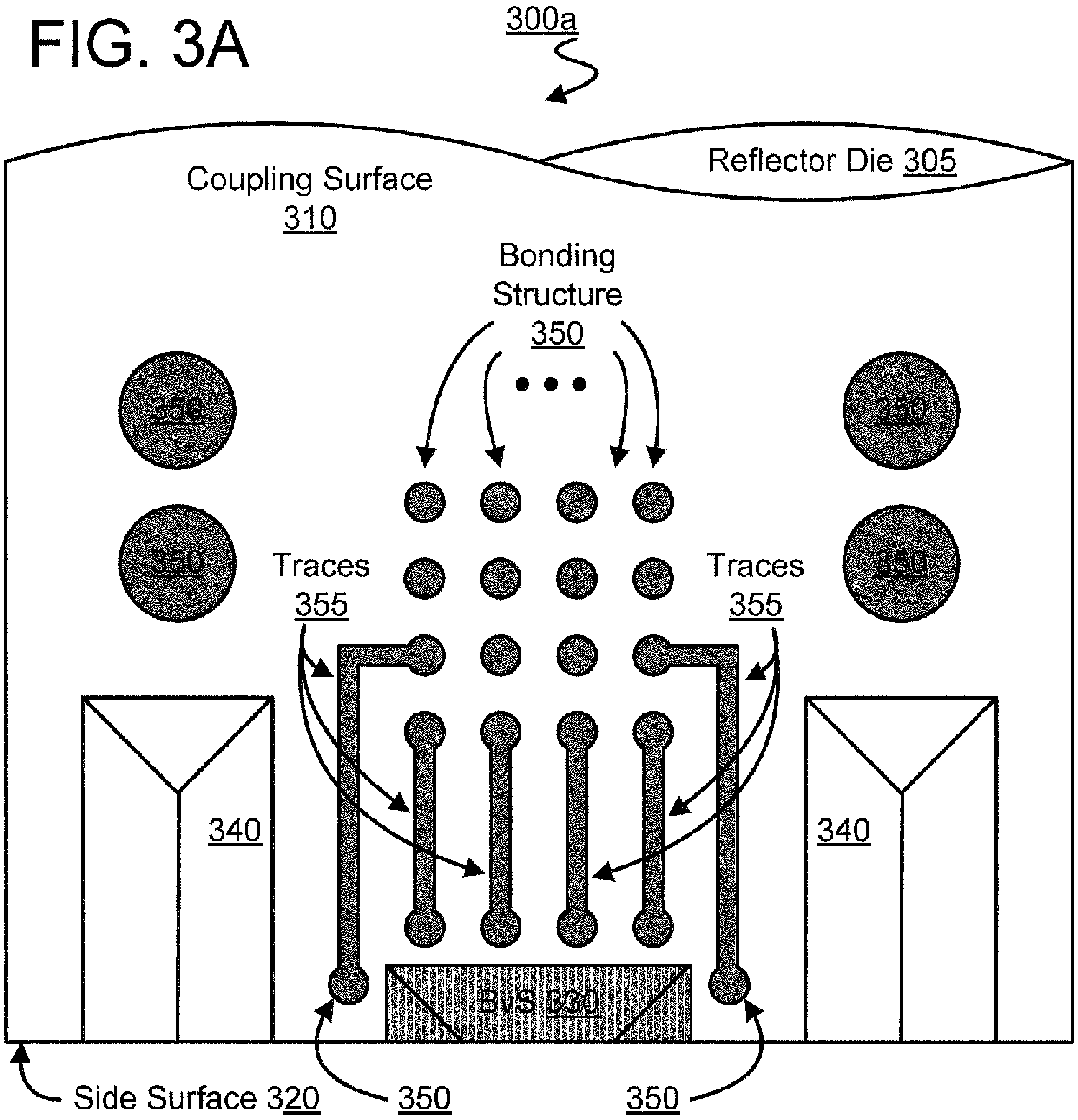

200
Coupling Surface 210
Reflector Die Substrate 205
245
215
Alignment Grooves 240
Bevel Groove 230
235
Side Surface Die Cut 225

FIG. 2

FIG. 3A


300a
Coupling Surface 310
Reflector Die 305
Bonding Structure 350
350
350
350
350
Traces 355
Traces 355
340
340
BvS 330
Side Surface 320
350
350

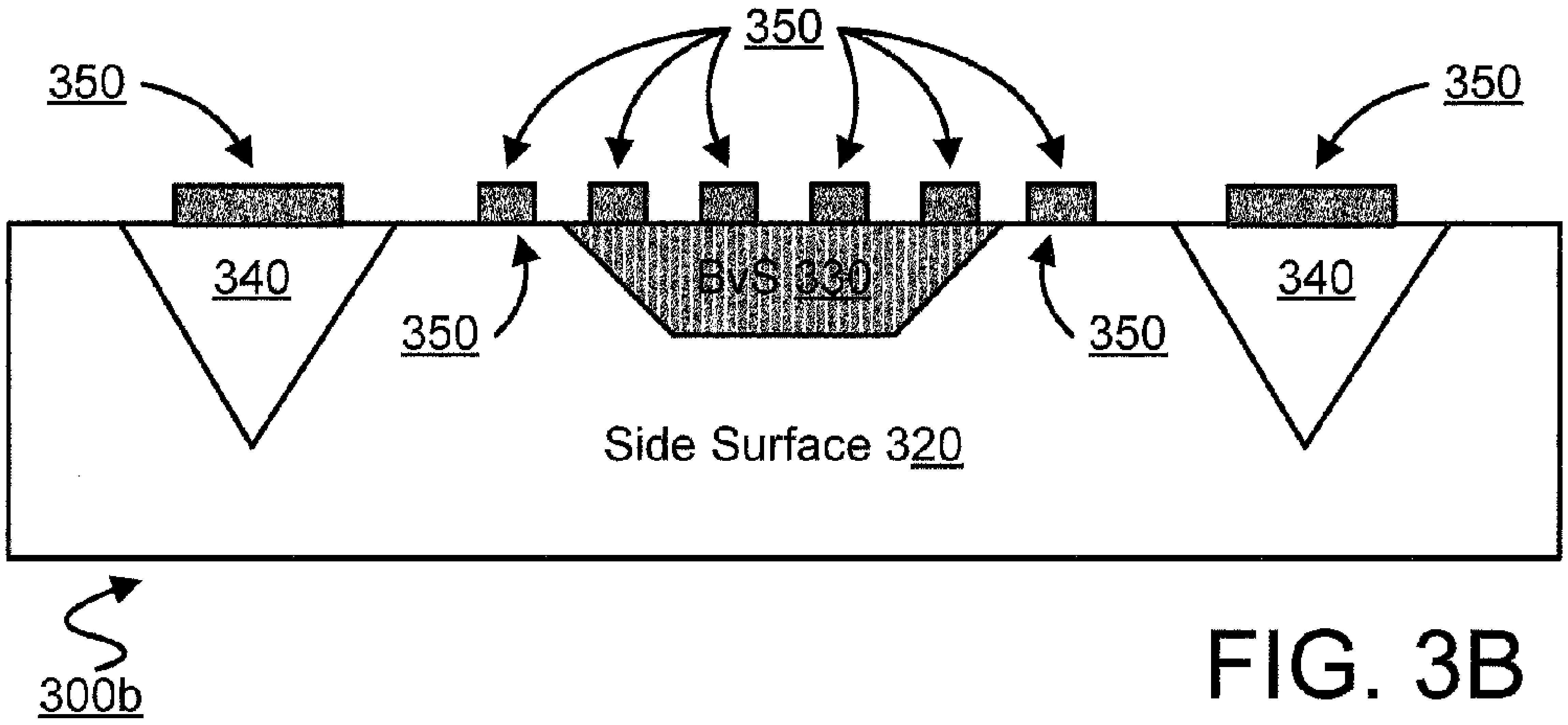
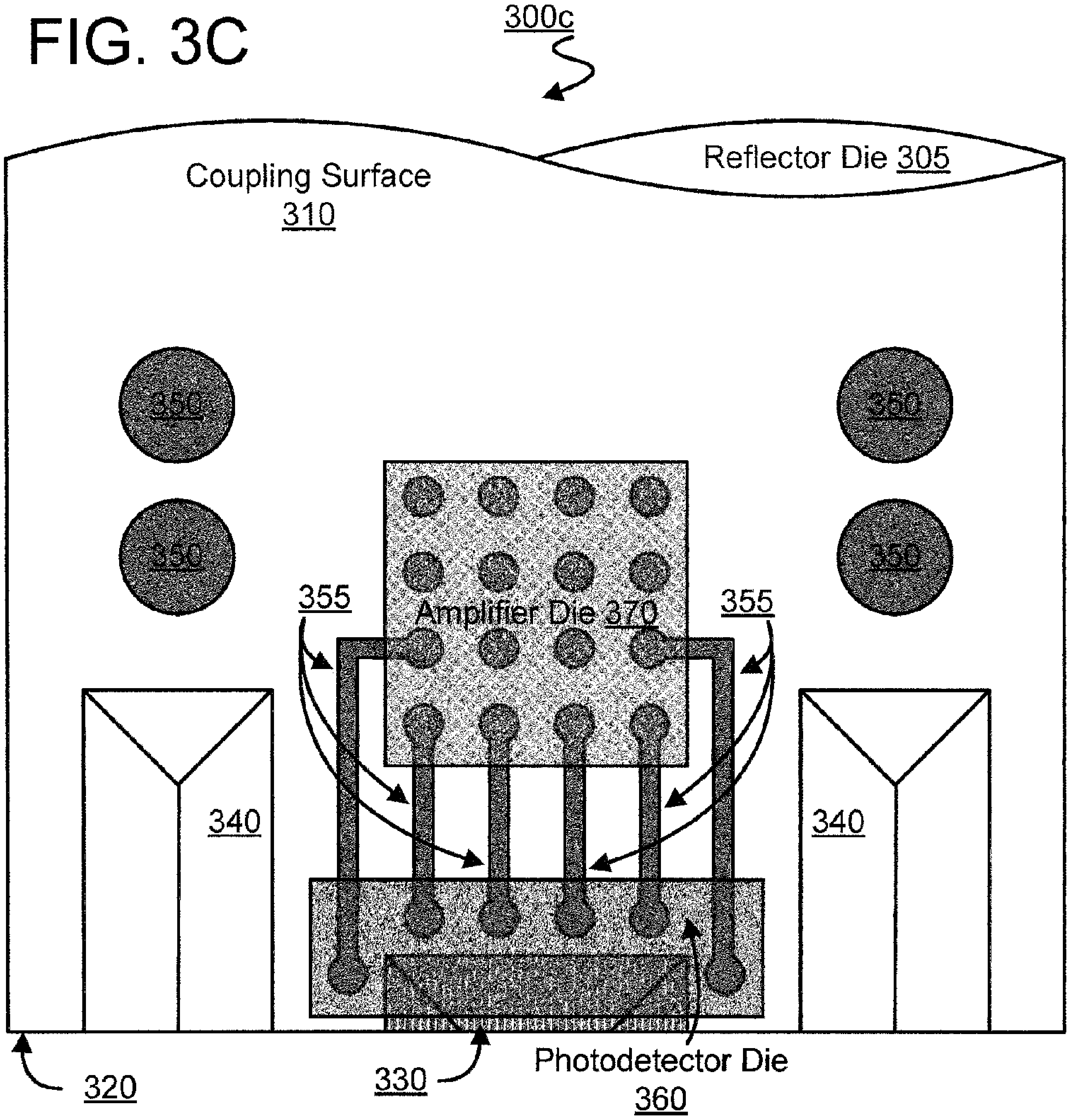

350
350
350
340
BvS 330
340
350
350
Side Surface 320
300b

FIG. 3B

FIG. 3C


300c
Reflector Die 305
Coupling Surface 310
350
350
350
350
355
355
Amplifier Die 370
340
340
320
330
Photodetector Die 360

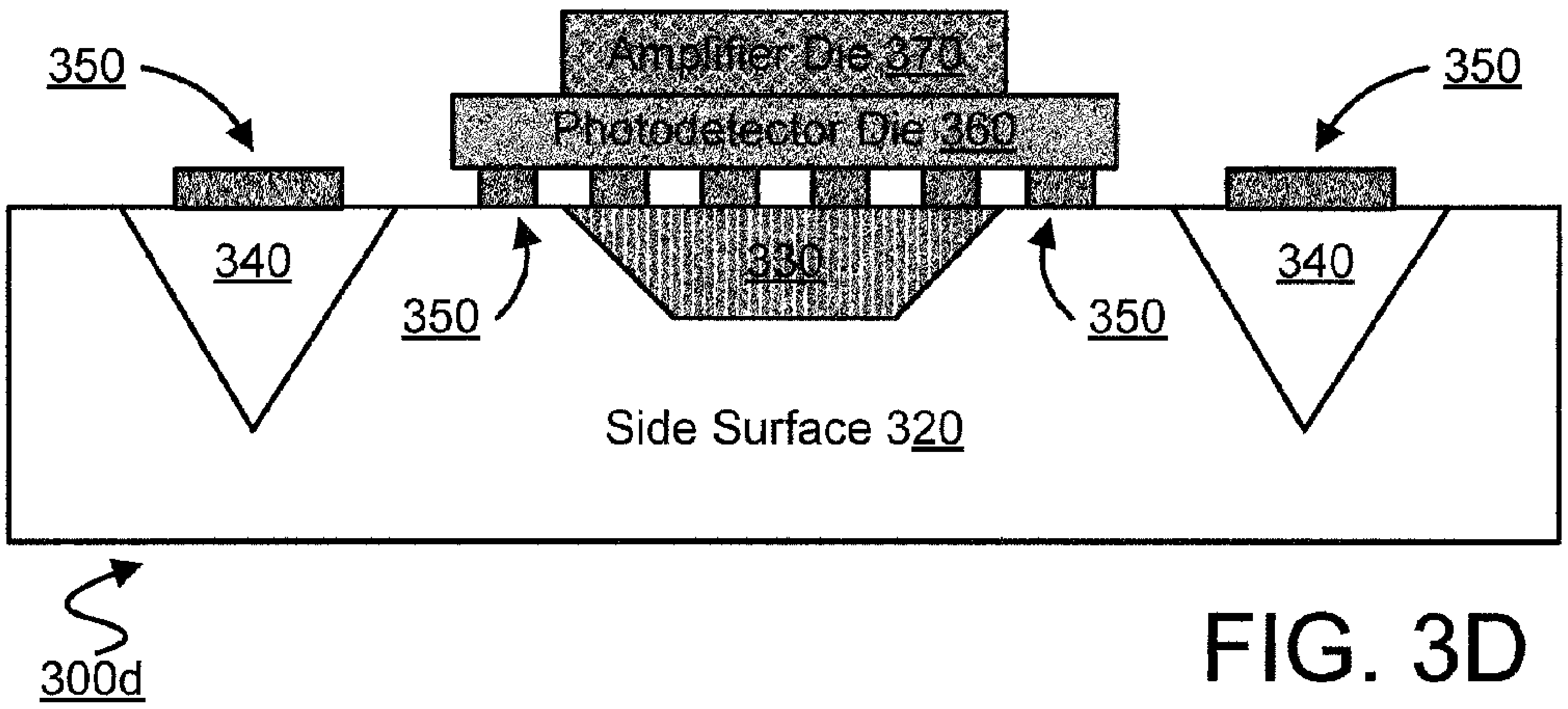
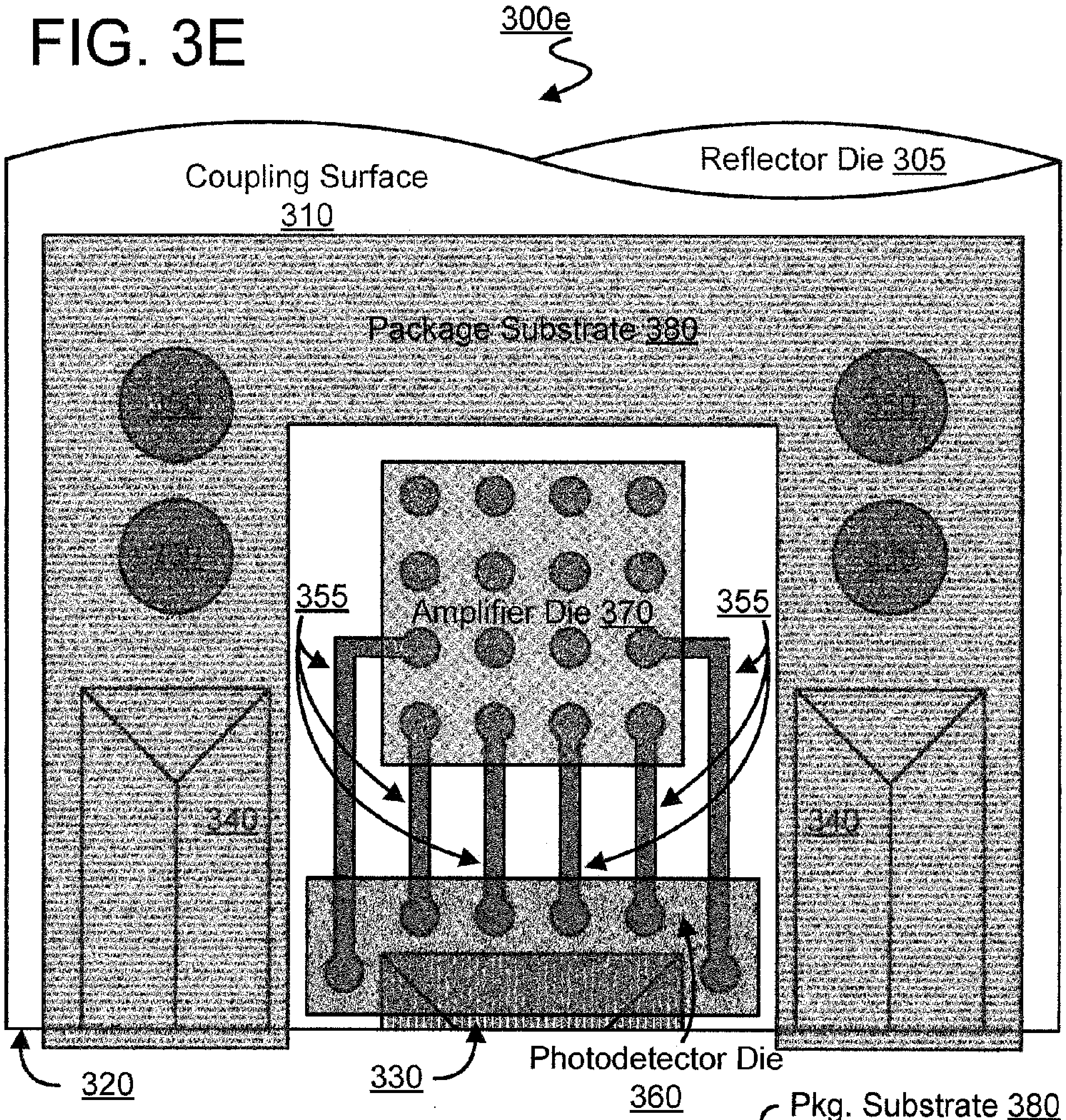

350
350
Amplifier Die 370
Photodetector Die 360
340
330
340
350
350
Side Surface 320
300d

FIG. 3D

FIG. 3E


300e
Coupling Surface 310
Reflector Die 305
Package Substrate 380
355
355
Amplifier Die 370
340
340
320
330
Photodetector Die 360

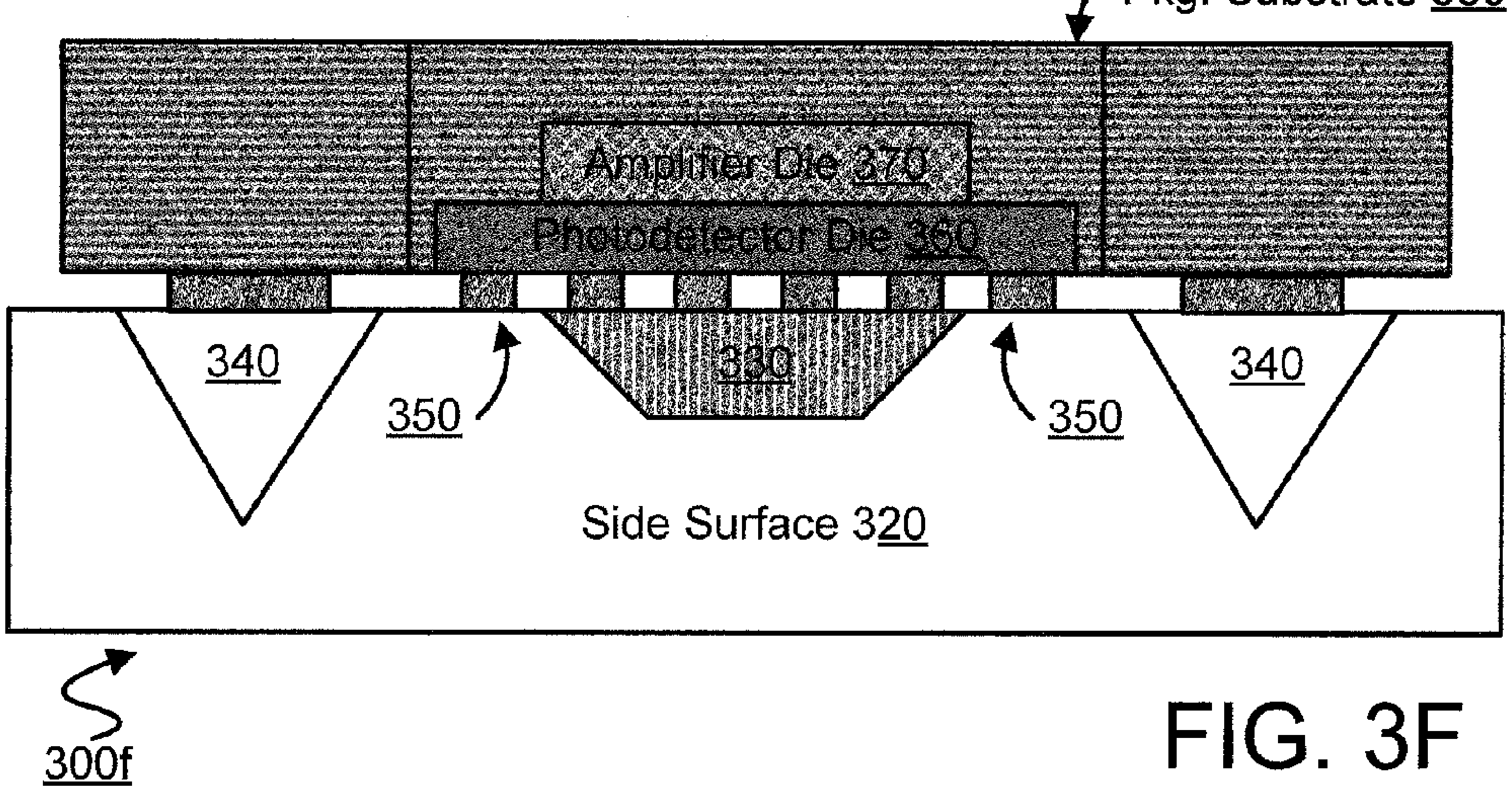

Pkg. Substrate 380
Amplifier Die 370
Photodetector Die 360
340
330
340
350
350
Side Surface 320
300f

FIG. 3F

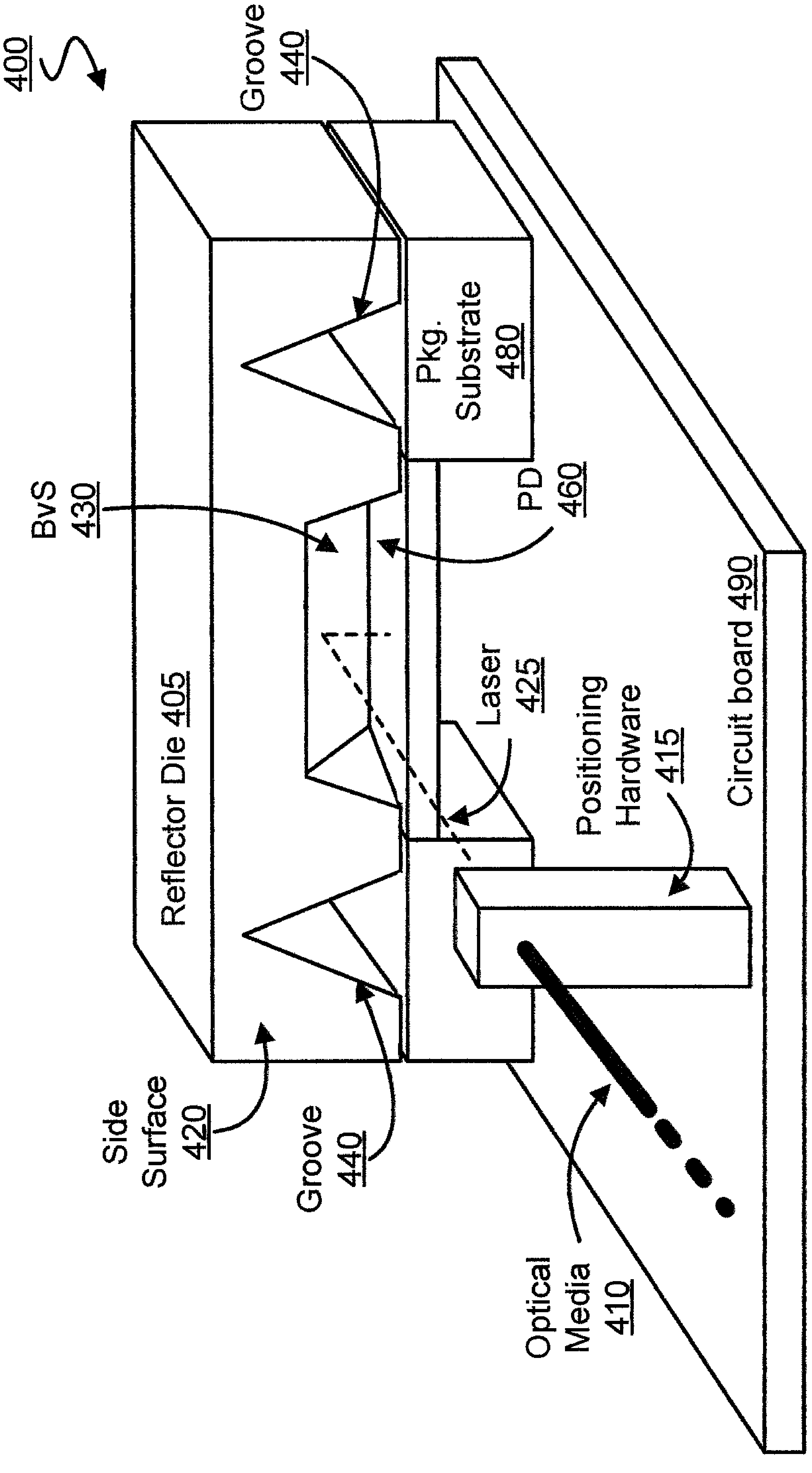

400
Groove 440
BvS 430
PD 460
Pkg. Substrate 480
Reflector Die 405
Laser 425
Positioning Hardware 415
Circuit board 490
Side Surface 420
Groove 440
Optical Media 410

FIG. 4

APPARATUS, METHOD AND SYSTEM FOR PROVIDING REFLECTION OF AN OPTICAL SIGNAL

BACKGROUND

1. Technical Field

Embodiments of the invention relate generally to structures for directing an optical signal in a photonic device. More particularly, certain embodiments relate to a reflector die for reflecting an optical signal into a photodetector for generating a corresponding electrical signal.

2. Background Art

Architectures for photonic devices often rely upon a silicon-layer-waveguide-based approach in which a planar silicon layer of a substrate functions as a waveguide to carry an optical signal. Due to the absorption qualities of silicon, such approaches can only be implemented for a limited range of optical signal wavelengths. For example, silicon layer waveguide structures are compatible with larger wavelength optical signals—e.g. lasers having wavelengths around 1310 nm. However, smaller wavelength optical signals—e.g. in the range of 850 nm—cannot be effectively exchanged, due to silicon's absorption coefficient at such wavelengths.

In these photonic device architectures, such a range of wavelengths can also constrain the use of photodetectors to convert optical signals into corresponding electrical signals. Photodetectors such as normal incidence photodetectors (NIPDs) may be fairly readily used for lasers operating in the 850 nm range, for example. However, for larger wavelength—e.g. 1310 nm—lasers, an NIPD's active area must be much smaller to achieve high-bandwidth performance at such larger wavelengths. For such larger wavelength signals, the required precision for aligning optics (e.g. lens, mirror, etc.) with such a small active area of a photodetector has been very difficult to achieve in volume.

BRIEF DESCRIPTION OF THE DRAWINGS

The various embodiments of the present invention are illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings and in which:

FIGS. **1**A through **1**C are block diagrams illustrating select elements of a reflector die according to an embodiment to provide a reflective target area for an optical signal.

FIG. **2** is a block diagram illustrating select elements of a substrate which is etched and cut to provide a reflector die according to an embodiment.

FIGS. **3**A and **3**B are block diagrams illustrating select elements of a method for metalizing a reflector die according to an embodiment.

FIGS. **3**C and **3**D are block diagrams illustrating select elements of a method for bonding a reflector die to create a die assembly according to an embodiment.

FIGS. **3**E and **3**F are block diagrams illustrating select elements of a method for packaging a die assembly according to an embodiment.

FIG. **4** is a block diagram illustrating select elements of a system for directing and processing an optical signal according to an embodiment.

DETAILED DESCRIPTION

Certain embodiments provide a reflector die allowing operation of an optical receiver which is compatible with 1310 nm as well as 850 nm optical signals, the latter of which is required for backward-compatibility with existing optical

communication standards. Unlike wave-guide based silicon photonics devices, various embodiments implement architectures wherein free-space optics can focus both wavelengths onto a normal-incidence photodetector (NIPD). In such architectures, optical signals may enter a die assembly along a side surface which is perpendicular to a base—e.g. a circuit board—to which the die assembly is connected.

Various embodiments comprise a reflector die fabricated from a substrate which is metalized to include an optical-quality facet to reflect light. The reflector die may also include optical alignment features such as V-grooves to provide precise alignment when bonding the reflector die to one or more other components. Certain embodiments further comprise a normal incidence photodetector (NIPD) and/or associated integrated circuits (ICs) such as a trans-impedance amplifier (TIA) bonded to the reflector die. The reflector die may furnish bondpads or similar bonding structures to which the NIPD and/or TIA may bond. Additionally or alternatively, the reflector die may include one or more traces for interconnecting components bonded thereto.

FIG. **1**A is block diagram illustrating—from a first view **100***a*—select elements of a reflector die **105**, according to an embodiment, to provide a target area for directing an optical signal. Reflector die **105** may be made from, or otherwise comprised of, a high resistance silicon substrate, where a low doping of the substrate mitigates capacitive effects in high frequency signal communications. First view **100***a* shows a coupling surface **110** of reflector die **105** for coupling reflector die **105** to one or more other dies—e.g. to form a die assembly. In an embodiment, such a die assembly may be packaged in a device for processing an optical signal which is received, for example, from a fiber-optic cable, waveguide, or other similar signal communication media.

One or more sides, or edges, of coupling surface **110** may be defined, respectively, by one or more other surfaces—referred to herein as side surfaces—of the reflector die **105** which adjoin coupling surface **110**. One or more such side surfaces may, for example, be considered "vertical" surfaces with respect to the comparatively "horizontal" coupling surface **110**. By way of illustration and not limitation, a side surface **120** of reflector die **105**—shown edge-on in view **100***a*—may at least partially adjoin coupling surface **110** to define a side thereof. Alternatively or in addition, side surface **120** may at least partially define a side of coupling surface **110** by providing a surface to which a bevel may be formed with coupling surface **110**. By way of illustration and not limitation, a bevel surface BvS **130** of reflector die **105** is formed by a bevel to coupling surface **110** and side surface **120**. Other side surfaces are shown in view **100***a* merely to illustrate some terminal extent of reflector die **105**.

In an embodiment, BvS **130** may provide a target area for an optical signal to be reflected by reflector die **105**. A reflective coating—indicated by a shaded region in view **100***a*—may be deposited on BvS **130** to reflect light (e.g. a laser signal) which is incident upon a target area thereof. In an embodiment, the reflective coating provides an optical quality mirror finish to at least a portion of BvS **130**. It is understood that additional, smaller and/or alternative reflective surfaces may be deposited on reflector die **105**, in various embodiments.

Reflector die **105** may further include one or more grooves in the coupling surface **110**, each of the one or more grooves providing a respective point of leverage for alignment of an optical signal target area of BvS **130**. In an embodiment, the one or more alignment grooves may variously extend along coupling surface **110** and through a side surface—such as surface **120**—defining a side of coupling surface **110**. Alternatively or in addition, the one or more alignment grooves may variously extend through a bevel surface such as BvS **130**. In the illustrative case of first view **100***a*, coupling surface **110** is shown as including two grooves **140** which each extend through side surface **120** on either side of the bevel forming BvS **130**.

It is understood that, according to various embodiments, reflector die **105** may include any of a variety of additional or alternate configurations of a bevel surface formed by a bevel to a coupling surface and a side surface and one or more grooves in the coupling surface for an aligning of a target area in the bevel surface.

FIG. **1**B is block diagram illustrating—from a second view **100***b*—select elements of reflector die **105**. View **100***b* shows side surface **120** face-on, while coupling surface **110** is viewed edge-on. In an embodiment, BvS **130** may, in combination with the reflective coating of BvS **130**, provide a target area which reflects an optical signal incident upon reflector die **105** after passing through a plane defined by side surface **120**. In an embodiment, BvS **130** is formed by a 54.7 degree or less bevel angle to the coupling surface **110**—e.g. a forty-five degree (45°) angle. For example, a 54.7 degree angle in a crystal plane may form naturally upon anisotropic etching. The angle may be less than 54.7 degrees if the chosen etchant to the crystal plane has lower selectivity.

View **100***b* also shows respective intersections of grooves **140** with side surface **120**. A particular groove **140** may be characterized, for example, according to a width along the side defined by coupling surface **110** and another surface—e.g. side surface **120**—through which the groove **140** extends. Alternatively or in addition, a groove **140** may be characterized according to a depth below coupling surface **110** and/or a length of extension along coupling surface **110** and away from the surface of intersection—e.g. side surface **120**. By way of illustration and not limitation, the width and depth of groove **140** may be 500 μm and 350 μm, respectively. However, it is understood that the respective dimensions of one or more grooves **140** may vary in different embodiments. For example, certain dimensions of the one or more grooves **140** may be chosen based on a particular alignment tool to be used in aligning a target area of BvS **130**.

In an embodiment, BvS **130** may be characterized according to a width of BvS **130** along a direction defined by intersecting planes defined, respectively, by coupling surface **110** and side surface **120**. Alternatively or in addition, BvS **130** may be characterized according to a length of extension in coupling surface **110** and away from side surface **120** and/or a length of extension in side surface **120** and away from coupling surface **110**.

In an embodiment, size, shape and/or orientation of BvS **130** may be chosen based on dimensions of one or more photodetectors to receive laser light which has been reflected from reflector die **105**. For example, one or more dimensions of BvS **130** may be chosen to present a particular target profile to a set of photodetector elements in a photodetector die (not shown) which is coupled to coupling surface **110**. In an embodiment, BvS **130** may have a length sufficient to present a target profile for each of a set of photodetector elements spanning a 1000-1500 μm length along a direction defined by intersecting planes defined, respectively, by coupling surface **110** and side surface **120**

FIG. **1**C is block diagram illustrating—from a third view **100***c*—select elements of reflector die **105**. In view **100***c*, both coupling surface **110** and side surface **120** are shown edge on. View **100***c* also illustrates for each of BvS **130** and a groove **140** a respective length of extension along coupling surface **110** and away from surface **120**. It is understood that, in various embodiments, the illustrated structures of reflector die **105** may vary—e.g. in terms of the shape and scale of groove **140**, the shape and scale of BvS **130** and/or the relative configuration of BvS **130** and groove **140** with respect to one another

FIG. **2** is a view **200** illustrating select elements of a reflector die substrate **205** according to an embodiment. Structures on reflector die substrate **205** may be formed on a substrate wafer, and then cut from the wafer to form a reflector die. In an embodiment, the resulting die includes some or all of the features of reflector die **105**. For example, a region of a coupling surface **210** of reflector die substrate **205** may correspond to coupling surface **110**, in an embodiment. Various side surfaces—e.g. side surface **215**—of the reflector die substrate **205** are illustrative of side surfaces which may be formed in a final resulting reflector die. However, it is understood that such side surfaces may not necessarily be yet formed at the time of fabricating other structures—e.g. various grooves—illustrated in view **200**.

Reflector die substrate **205** may include a bevel groove **230** and one or more alignment grooves **240** formed in coupling surface **210**. At some point during fabrication, part of the cutting of a reflector die out of reflector die substrate **205** may include performing a side surface die cut **225**. For example, side surface die cut **225** may cut along—e.g. bisect—the length of bevel groove **230** so that a portion of bevel groove **230**, which remains as part of the resulting die, forms a bevel between coupling surface **210** and the side surface which results from side surface die cut **225**. The resulting bevel may include some or all of the features of BvS **130**, in an embodiment.

In an embodiment, some or all of bevel groove **230** and the one or more alignment grooves **240** may be formed in coupling surface **210** before a final reflector die is cut from reflector die substrate **205**. Such grooves in coupling surface **210** may be formed using a crystallographic etch process such as a potassium hydroxide (KOH) etch, a tetra methyl ammonium hydroxide (TMAH) etch, an ethylene diamine pyrocatechol (EDP) etch, an ammonium hydroxide (NH4OH) etch or other such etch process. The etch process may form some or all of the illustrated groove structures in reflector die substrate **205**—using a patterned silicon nitride or thermal oxide mask, for example.

After formation of the one or more grooves **240** and bevel groove **230**, an area of coupling surface **110** may be metalized—e.g. including depositing a reflective coating on a surface of bevel groove **230**. For example, an area of bevel groove **230** which is to form the bevel surface of the final resulting reflector die may be coated with gold (Au) to provide reflectivity of a target area thereon. Such metallization may be performed with sputtering, evaporation, or other such techniques for depositing a gold or other reflective metal coating to give the bevel surface an optical quality mirror finish.

After formation of bevel groove **230** and one or more alignment grooves **240** in reflector die substrate **205**, and after metallization of at least the reflective portion of bevel groove **230**, a reflector die including these grooves may be cut from reflector die substrate **205**, including performing side surface die cut **225**. It is understood that cutting the reflector die from reflector die substrate **205** may be performed after additional structures for the reflector die (not shown) are fabricated on reflector die substrate **205**. For example, side surface die cut **225** and/or any other such cuts may be performed after signal traces and/or bonding structures (e.g. bond pads and/or stud bumps) have been variously deposited on the coupling surface **210**. Additionally or alternatively one or more other dies may be bonded to the coupling surface **210** before the reflector die is cut from the reflector die substrate **205**—i.e. where the die as cut is already coupled to the one or more other dies. In an embodiment, the reflector die is cut from reflector die substrate **205** prior to any bonding of the reflector die to a packaging substrate.

For the sake of illustrating features according to certain alternate embodiments, view **200** shows an alternate position **235** for a bevel groove and an alternate position **245** for an alignment groove. Alternate position **235** is illustrative of an embodiment in which, in a final resulting die cut from reflector die substrate **205**, an alignment groove **240** will extend through the bevel which is fabricated from the alternate bevel groove **235**. Additionally or alternatively, alternate position **245** is illustrative of an embodiment in which, in a final resulting die cut from reflector die substrate **205**, an alternate alignment groove **245** will extend through a side face **215** which is not the side face of the bevel formed from bevel groove **230**. It is understood that various other configurations of alignment groove **240** and bevel groove **230** with respect to one another may be implemented, according to various embodiments.

FIG. **3**A is a first view **300***a* illustrating select elements of a method to fabricate, according to an embodiment, an apparatus for directing an optical signal. The fabrication may include operations to create various structures of a reflector die **305**. Reflector die **305** may include some or all of the features of reflector die **105**, for example. In an embodiment, reflector die **305** may represent the final resulting reflector die cut from reflector die substrate **205**.

In an embodiment, fabrication of structures for reflector die **305** may include etching one or more alignment grooves **340** in a coupling surface **310** for reflector die **305**, and forming a bevel surface BvS **330** by creating a bevel between coupling surface **310** and a side surface **320** of reflector die **305**. Creation of BvS **330** may, for example, be according to according to the techniques described with respect to bevel groove **230**. Fabrication of structures for reflector die **305** may further include depositing of a reflective coating on BvS **330**. Although shown as a separate reflector die **305**, it is understood that various ones of the fabrication operations illustrated in FIGS. **3**A-**3**F may be performed before the reflector die **305** has been cut from a substrate wafer.

Metallization processes may additionally or alternatively be implemented to dispose on coupling surface **310** one or more traces **355** and/or one or more bonding structures **350**—e.g. bond pads and/or stud bumps. The particular number, size, shape, configuration, etc. of such traces **355** and/or bonding structures **350** may depend on one or more dies to be bonded with coupling surface **310**. In an embodiment, metals such as gold or nickel/gold may be deposited to form such traces **355** and/or bonding structures **350**—e.g. using deposition processes compatible with the topography existing on the substrate wafer of reflector die **305**. For example, lithography may be applied using spray coating or an electro-deposit resist if standard thick-resist spin-coating is not possible.

FIG. **3**B is a second view **300***b* illustrating select elements of the fabrication method illustrated in FIG. **3**A. View **300***b* shows side surface **320** face-on, while coupling surface **310** is viewed edge-on. It is understood that, in an embodiment, side surface **320** may be formed only after additional or alternate structures are etched in, and/or deposited on, a substrate wafer from which reflector die **305** is later cut.

FIG. **3**C is a third view **300***c* illustrating select elements of the fabrication method illustrated in FIGS. **3**A and **3**B. View **300***c* illustrates an exemplary embodiment in which a die assembly is created by bonding one or more integrated circuit dies to coupling surface **310**.

For example, a photodetector die **360** may be bonded to one or more bonding structures **350** disposed on coupling surface **310**. The photodetector may be, for example, a germanium photo-diode, or other type of photodetector. Photodetector die **360** may include one or more photodetector elements to receive an optical signal for conversion to a corresponding electrical signal. In an embodiment, photodetector die **360** may include one or more normal-incidence amplifiers. Bonding photodetector die **360** to coupling surface **360** may include positioning an active area—e.g. a detecting area—of photodetector die **360** to overlap and face an area of BvS **330** on which the reflective coating is disposed. For example, an overlap of BvS **330** with an active area of photodetector die **360** may be, for example, along a direction normal to side surface **320**. Such positioning of photodetector die **360** with respect to the reflective coating of BvS **330** may allow an optical signal incident upon a target area of BvS **330** to reflect onto an active area of photodetector die **360**.

Additionally or alternatively, an amplifier die **370** may be bonded to one or more other bonding structures **350** disposed on coupling surface **310**. In an embodiment, the one or more boding structures **350** which bond to photodetector die **360** and the one or more other boding structures **350** which bond to amplifier die **370** may be variously coupled by respective ones of traces **355** disposed on coupling interface. Such traces **355** may allow photodetector die **360** to provide to amplifier **370** an electrical signal generated by detecting and converting an optical signal reflected from BvS **330**. Amplifier die **370** may amplify a signal received from photodetector die **360** via traces **355** before providing the amplified signal to other circuit components (not shown). In an embodiment, amplifier die **370** includes a transimpedance amplifier (TIA).

Photodetector die **360** and amplifier die **370** may each include respective bonding structures (e.g. bond pads and/or stud bumps, not shown) for bonding to corresponding ones of bonding structures on coupling surface **310**. In one embodiment, photodetector die **360** and/or amplifier die **370** may, for example, have aluminum, gold or similar pads which are gold stud bumped. Either or both dies may then be bonded to respective ones of bonding structures **350**. Such bonding may be performed, for example, using thermocompression or thermosonic bonding.

FIG. **3**D is a fourth view **300***d* illustrating select elements of the fabrication method illustrated in FIGS. **3**A to **3**C. View **300***d* shows side surface **320** face-on, while coupling surface **310** is viewed edge-on. In an embodiment, bonding of photodetector die **360** and/or amplifier die **370** to coupling surface **310** may be performed after reflector die **305** has been cut from a substrate wafer. Cutting reflector die **305** from the substrate wafer may variously create one or more of the side surfaces—e.g. including side surface **320**—wherein the alignment grooves **340** variously extend through respective ones of the one or more side surfaces.

Extension of an alignment groove though a side surface—e.g. one or more grooves **340** though side surface **320**—and/or BvS **130** may provide access to the alignment groove **340**. The one or more alignment grooves **340** may therefore provide respective leverage points for alignment pins to give precise alignment of a die with respect to a target area of BvS **330** for coupling the die to coupling surface **310**. In an embodiment, some or all of alignment grooves **340** may receive respective aligning pins imparting leverage for precise manipulation, positioning and/or securing of photodetector die **360** and/or amplifier die **370** for bonding to coupling surface **310**.

FIG. **3**E is a fifth view **300***e* illustrating select elements of the fabrication method illustrated in FIGS. **3**A to **3**D. View **300***e* illustrates features of an operation to package the die assembly shown in view **300***c*. In an embodiment, a die assembly including reflector die **305**, photodetector die **360** and amplifier die **370** may be bonded to a package substrate **380**—e.g. with one or more bonding structures **350** disposed on coupling surface **310**. The package substrate **380** may be a laminate material such as FR-4 or other such material used in integrated circuit packaging. Package substrate **380** is illustrative of one type of packaging substrate, and it is understood that any of a variety of additional or alternative packaging structures may be bonded to the die assembly. Bonding of package substrate **380** may, for example, be done using a standard soldering process. In one embodiment, a Ni/Au deposition of bond structures **350** would function as an underbump metallurgy compatible with a standard lead-free solder to form this connection, with nickel as a barrier and gold as a whetting material.

FIG. **3**F is a sixth view **300***f* illustrating select elements of the fabrication method illustrated in FIGS. **3**A to **3**E. The combination of die assembly and package substrate **380** may be provided as, or incorporated into, an apparatus for receiving an optical signal for conversion to an electrical signal. Such an apparatus may include an optical universal serial bus (USB) device, for example.

FIG. **4** is a high-level illustration of select elements in a system **400** according to an embodiment, the system **400** for directing and processing an optical signal. System **400** may include optical signal reflecting and conversion structures such as those generated by the operations of FIGS. **3**A through **3**F. In an illustrative embodiment, system **400** may include a die assembly including a reflector die **405**, photodetector die PD **460**, and package substrate **480**. System **400** may further include an amplifier (not shown) to amplify an electric signal which PD **460** generates by converting an optical signal.

For example, system **400** may include an optical media **410**—e.g. a fiberoptic cable or waveguide—to direct a laser signal **425** to a bevel surface BvS **430** of reflector die **405**. A circuit board **490** may include or couple to positioning hardware **415** to position and/or orient the optical media **410** for direction of laser **425** toward a target area of BvS **430**. In an embodiment, BvS **430** may include a reflective coating on the target area to reflect the laser signal **425** onto an active area of PD **460**. It is understood that grooves **440** and/or BvS **430** may vary in scale or configuration—e.g. either in relation to one another and/or in relation to other structures in system **400**. In an embodiment, cylindrical pins (not shown) may be affixed into grooves **440** and extend outward perpendicular from the side surface **420**, such that a molded plastic lens array may be attached with high precision to the system **400** using these pins for alignment.

Techniques and architectures for providing a reflective target area for an integrated circuit die assembly are described herein. In the above description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of certain embodiments. It will be apparent however, to one skilled in the art, that certain other embodiments can be practiced without these specific details. In other instances, structures and devices are shown in block diagram form in order to avoid obscuring the description.

Reference in the specification to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the invention. The appearances of the phrase "in one embodiment" in various places in the specification are not necessarily all referring to the same embodiment.

Some portions of the detailed descriptions herein are presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the computing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of steps leading to a desired result. The steps are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the discussion herein, it is appreciated that throughout the description, discussions utilizing terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

Certain embodiments also relate to apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may comprise a general purpose computer selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but is not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, and magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs) such as dynamic RAM (DRAM), EPROMs, EEPROMs, magnetic or optical cards, or any type of media suitable for storing electronic instructions, and each coupled to a computer system bus.

The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the required method steps. The required structure for a variety of these systems will appear from the description herein. In addition, certain embodiments are not described with reference to any particular programming language. It will be appreciated that a variety of programming languages may be used to implement the teachings of certain embodiments as described herein.

Besides what is described herein, various modifications may be made to the disclosed embodiments and implementations thereof without departing from their scope. Therefore, the illustrations and examples herein should be construed in an illustrative, and not a restrictive sense. The scope of the invention should be measured solely by reference to the claims that follow.

What is claimed is:

1. An apparatus comprising:

a reflector die including:

one or more side surfaces including a first side surface;

a coupling surface to couple the reflector die;

a flat bevel surface formed by a bevel to a first flat portion of the coupling surface and to a second flat portion of the first side surface, the bevel surface to provide a target area for an optical signal, wherein the bevel surface and the one or more side surfaces define one or more edges the coupling surface, wherein the one or more side surfaces are each perpendicular to and face away from the coupling surface, and wherein the bevel surface faces away from the second flat portion;

one or more grooves in the coupling surface, each of the one or more grooves extending through a respective one of the bevel surface and the one or more side surfaces, the one or more grooves each to receive a respective alignment pin for an aligning of the target area; and

a reflective coating deposited on the bevel surface, the reflective coating to reflect the optical signal.

2. The apparatus of claim **1**, the reflector die further comprising bonding structures coupled to the coupling surface.

3. The apparatus of claim **2**, further comprising:

a photodetector die coupled to the coupling surface via the bonding structures, the photodetector die to receive the reflected optical signal, the photodetector die further to convert the optical signal into an electrical signal.

4. The apparatus of claim **2**, the reflector die further comprising one or more traces deposited on the coupling surface, the one or more traces coupled to the bonding structures.

5. The apparatus of claim **4**, further comprising:

a photodetector die coupled to coupling surface, the photodetector die to receive the reflected optical signal, the photodetector die further to convert the optical signal into an electrical signal, wherein the one or more traces to communicate the electrical signal from the photodetector.

6. The apparatus of claim **4**, further comprising:

an amplifier die coupled to the one or more traces to receive and to amplify an electrical signal.

7. A method comprising:

etching in a coupling surface of a reflector die substrate:

one or more alignment grooves; and

a bevel groove;

depositing a reflective coating on a surface of the bevel groove; and

after the etching, cutting a reflector die from the reflector die substrate, the cutting forming one or more side surfaces defining one or more edges of the coupling surface, wherein the one or more side surfaces are each perpendicular to and face away from the coupling surface, the cutting including performing a cut to form a first side surface of the one or more side surfaces, the cut bisecting the bevel groove to form a bevel to a first flat portion of the coupling surface and to a second flat portion of the first side surface, the bevel including a flat bevel surface having the reflective coating deposited thereon, wherein the bevel surface faces away from the second flat portion, wherein the one or more alignment grooves each extend through a respective one of the bevel surface and the one or more side surfaces.

8. The method of claim **7**, further comprising depositing bonding structures to the coupling surface.

9. The method of claim **8**, further comprising bonding a photodetector die to the coupling surface via the bonding structures.

10. The method of claim **9**, wherein the bonding the photodetector die includes aligning the bevel surface and the photodetector die, the aligning including applying leverage to the reflector die via the one or more alignment grooves.

11. The method of claim **8**, further comprising depositing one or more traces on the coupling surface, the one or more traces coupled to the bonding structures.

12. The method of claim **11**, further comprising bonding a photodetector die to the coupling surface, including coupling the photodetector die to the one or more traces via the bonding structures.

13. The method of claim **11**, further comprising bonding an amplifier die to the coupling surface, including coupling the amplifier die to the one or more traces via the bonding structures.

14. A computer-readable storage medium having stored thereon instruction which, when executed by one or more processors, cause the one or more processors to perform a method comprising:

etching in a coupling surface of a reflector die substrate:

one or more alignment grooves; and

a bevel groove;

depositing a reflective coating on a surface of the bevel groove; and

after the etching, cutting a reflector die from the reflector die substrate, the cutting forming one or more side surfaces defining one or more edges of the coupling surface, wherein the one or more side surfaces are each perpendicular to and face away from the coupling surface, the cutting including performing a cut to form a first side surface of the one or more side surfaces, the cut bisecting the bevel groove to form a bevel to a first flat portion of the coupling surface and to a second flat portion of the first side surface, the bevel including a flat bevel surface having the reflective coating deposited thereon, wherein the bevel surface faces away from the second flat portion, wherein the one or more alignment grooves each extend through a respective one of the bevel surface and the one or more side.

15. The computer-readable storage medium of claim **14**, the method further comprising depositing bonding structures to the coupling surface.

16. The computer-readable storage medium of claim **15**, the method further comprising bonding a photodetector die to the coupling surface via the bonding structures.

17. The computer-readable storage medium of claim **16**, wherein the bonding the photodetector die includes aligning the bevel surface and the photodetector die, the aligning including applying leverage to the reflector die via the one or more alignment grooves.

18. The computer-readable storage medium of claim **15**, the method further comprising depositing one or more traces on the coupling surface, the one or more traces coupled to the bonding structures.

19. The computer-readable storage medium of claim **18**, the method further comprising bonding a photodetector die to the coupling surface, including coupling the photodetector die to the one or more traces via the bonding structures.

20. The computer-readable storage medium of claim **18**, the method further comprising bonding an amplifier die to the coupling surface, including coupling the amplifier die to the one or more traces via the bonding structures.

21. A system comprising:

a reflector die including:

one or more side surfaces including a first side surface;
a coupling surface to couple the reflector die;
a flat bevel surface formed by a bevel to a first flat portion of the coupling surface and to a second flat portion of the first side surface, the bevel surface to provide a target area for an optical signal, wherein the bevel surface and the one or more side surfaces define one or more edges the coupling surface, wherein the one or more side surfaces are each perpendicular to and face away from the coupling surface, and wherein the bevel surface faces away from the second flat portion;
one or more grooves in the coupling surface, each of the one or more grooves extending through a respective one of the bevel surface and the one or more side surfaces, the one or more grooves each to receive a respective alignment pin for an aligning of the target area; and a reflective coating deposited on the bevel surface, the reflective coating to reflect the optical signal; and a circuit board coupled to the reflector die to exchange one or more signals based on the optical signal.

22. The system of claim **21**, the reflector die further comprising bonding structures coupled to the coupling surface.

23. The system of claim **22**, further comprising:
a photodetector die coupled to the coupling surface via the bonding structures, the photodetector die to receive the reflected optical signal, the photodetector die further to convert the optical signal into an electrical signal.

24. The system of claim **22**, the reflector die further comprising one or more traces deposited on the coupling surface, the one or more traces coupled to the bonding structures.

25. The system of claim **24**, further comprising:
a photodetector die coupled to coupling surface, the photodetector die to receive the reflected optical signal, the photodetector die further to convert the optical signal into an electrical signal, wherein the one or more traces to communicate the electrical signal from the photodetector.

26. The system of claim **24**, further comprising:
an amplifier die coupled to the one or more traces to receive and to amplify an electrical signal.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO.	: 8,530,818 B2
APPLICATION NO.	: 12/825257
DATED	: September 10, 2013
INVENTOR(S)	: Heck et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Specification

Please insert in column 1, line 5 before BACKGROUND:

--STATEMENT OF GOVERNMENT INTEREST

This invention was made with Government support under contract number H98230-08-3-0011 awarded by the Department of Defense. The Government has certain rights in this invention.--

Signed and Sealed this
First Day of December, 2015

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office